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CONTRIBUTIONS TO THE LIFE-HISTORY OF PLANTS. No. XV.

BY THOMAS MEEHAN.

The Bending of Mature Wood in Trees.

At the meeting of the American Association for the Advancement of Science held in Philadelphia in 1884, Prof. Charles E. Bessey exhibited a drawing of the trunk of a Balsam Fir that had blown over and had bent in such a manner that the curvature could only have occurred after the trunk had become several years old. The prevalent impression is that trees and branches grow into their various forms; or, as the popular phrase expresses it, "as the twig is bent the tree's inclined." No one was prepared to believe that the tree, once inclined, could at any time thereafter change its form. There was nothing in the text-books to indicate the possibility of such phenomena. Prof. Bessey's specimen was looked upon as interesting and curious, but it has had no influence in our text-book teachings. Up to the present time we are taught to look to light, gravitation, tension, turgescence, or some one or another of the surrounding conditions to account for the direction which stems or branches assume—the independent energy developed from plant life itself receiving but slight recognition, probably because its exact nature is so far incomprehensible. Prof. Bessey's experience seemed to throw more light on some of my own observations. In the *Proceedings* of the Academy of Natural Sciences of Philadelphia for 1866, p. 401, appears my paper "On the Consumption of Force by Plants in Overcoming Gravitation," in which is clearly shown that life-energy, sustained by nutrition, was an enormous power in the life-history of the plant. I was encouraged to make actual experiments and wide observations, that have extended from that time till now, only to find the surprising fact that the recurving and incurving of mature growth is among the commonest of phenomena in the vegetable world. Before proceeding to prepare this paper, I inquired of Prof. Bessey if he had investigated the matter further, and received the following interesting letter:

"LINCOLN, NEB., Dec. 29, 1900.

"*My Dear Professor Meehan:*—In regard to the bending of the mature internodes of conifers, I may say that it was in 1884 that I made the first public statement before the Botanical Club of the A. A. A. S., or possibly before the Biological Section itself. It was to the effect that in the spring of the year 1882 (exactly April 8) a tornado crossed the campus of the Agricultural College at Ames, Ia , and among other things which it did, it partly uprooted a number of conifers, bending them over almost to the ground in some cases. After a while I noticed that these trees were bending upward, and that the bending was not confined to the youngest internodes, but that the older internodes were more or less bent also. I noticed this particularly in the case of some Balsam Fir trees, *Abies balsamea,* in which the bending extended several years back of the time when the trees were first partly uprooted.

" This year (in August) I had the opportunity of noticing the same thing in connection with the Foxtail Pine, *Pinus flexilis* var. *Murrayana,* in the Yellowstone Park A slender tree had been bent to the ground by the fall of a larger tree, and yet the smaller tree had been able to bend a considerable portion of its top so as to bring it approximately erect. A careful examination of the larger tree in regard to the time of its fall made it certain, that several of the mature internodes of the smaller tree bent after reaching the horizontal position. I have seen something like this in case of the destruction of the central ' leader ' of the Austrian Pines on the University campus, during the past ten or twelve years, but these cases are not as striking as those cited above.

" I am glad that you are to bring this out, as I know that it will be so done that there will be no doubt at all in regard to it.

" I am very truly, etc.,

"CHARLES E. BESSEY."

My own work began by inclining an Arbor Vitæ, *Thuja occidentalis,* to an angle of about 45°. It was about eight feet high and perfectly straight. About the middle of May the following year the apex began to curve upwardly. The process continued for about three weeks, by which time the curving had extended down to some three feet, reaching the five-year-old wood of the main stem. In the course of this process the upper portion, that had commenced the incurving motion, would again become erect, so that the curve would only occupy a few feet in extent in the region of the three to five-year-old wood. The upper or erect portion would, however, be considerably out of line with the perpendicular of the tree's original growth from the ground. The following year the incurve extended down to the six or seven-year wood, and the upper portion recurved so that it might again assume a perpendicular position. No further curving occurred in after years. The tree is yet one of the curiosities on my grounds.

Following this was an experiment with a Lawson Cypress, *Cupressus Lawsoniana.* The results were similar, the incurving being just after active growth in spring.

So far we have the lesson from direct experiment. But when we look around us we see the bending power abundantly illustrated. The Galena Weeping Elm, a form of *Ulmus Americana,* grafted on stems eight or ten feet high, starts from the first with cord-like pendent branches reaching to the ground. But I have trees between thirty and forty years old that are nearly as many feet high. I have never seen an erect one-year-old branch on the trees. At the end of every branch there is pendent a growth of two or three years. For several years I have watched a leading branch that is straight and nearly horizontal, now over twenty feet in length ; a pendent growth of three years is always at its terminus. I find that in June the third year's growth straightens, the new growth still forming a continuous three-year bend. The Weeping Willow will occasionally make a few vigorous straight stems to aid in the upward growth, but the majority of the curved branches take to straightening after two or three years. The Hemlock Spruce, *Abies canadensis,* curves its new growth, which continues curved till the next season, when it rapidly becomes erect, the new growth taking the curve of the previous year.

The most interesting features of the study relate to the incurving and recurving of very old branches. In many trees there is no evidence of a tendency to bend till after the fifth year. For some ten years after this, or in ten- or fifteen-year-old wood, the phenomena is common. It may often be seen in the Tulip Poplar, *Liriodendron tulipifera,* the White Ash, *Fraxinus Americana,* the Pear tree, and many others. One of the best illustrations is afforded by the Horse Chestnut, *Æsculus Hippocastanum.* The branches all keep at an acute angle till the tree reaches an age of about twenty-five years. Then the ten-year-old branches begin to droop from near the basal region at the trunk. They spend several years in curving downward, and then make an incurve between the recurve and the apex. This method of first becoming a little more horizontal, then recurving near the base and incurving toward the apex is quite common among coniferous trees. The actual bending of the main trunk, which Prof. Bessey and myself ascertained by actual observation in three species of coniferæ, may have another illustration in a specimen of the Himalayan Pine, *Pinus excelsa*, on the estate of Caspar Heft in Germantown. It is about fifty years old, and probably among the earliest introduced to American gardens. The heavy trunk is curved from near the ground to about twenty feet upwardly. The verticels of branches in this species of Pine extend all around the trunk in a regular horizontal line. In the curved portion of this tree the straight branches on one side are directed above the horizontal line, on the other side they point below. There can be no other explanation of this than that the tree blew over when about twenty-five feet high, and that the whole of this early twenty-five-year growth had been made to curve.

Most species of trees will have some of their mature branches incurve or recurve at various ages; and this curving is often characteristic of the species. The list is made up from specimens growing on my own property, with the exception of a few left of the original forest, all planted by myself within the past forty years:

Magnolia.

In *M. tripetela, M. Fraseri, M. conspicua* and *M. macrophylla* I observe no disposition to curve at any age. But *M. acuminata* sends out its upper branches at an acute angle, with the apices incurved. After about five years they commence to descend by a curve near the base. These curves of the lower branches increase in width, until finally the upper portions of the branches again incurve, as noted in many coniferæ, especially of the Spruce family. Plate XVI represents a thirty-five-year-old tree.

Tilia.

The Lindens : No curving observed in *T. Europœa,* but in mature trees of *T. Americana* they are common and striking.

Ilex.

I have no large specimens of *I. Aquifolium.* In bushy specimens of *I. opaca* no curving noticed ; but where the plant has assumed a tree-form descent commences in the five-year-old branches, and they finally curve and recurve as in the Spruces.

Kœlreuteria.

This seems naturally tortuous; but the branches, once formed, seem unchangeable.

Æsculus.

A. Hippocastanum recurves remarkably, even in branches of considerable age.

Acer.

The Maple family : *A. dasycarpum,* the Silver Maple, is remarkable for its eccentricity as regards the curving of its branches. One form known in gardens as "Wier's Cut-leaved," has cord-like pendulous branches, some of which straighten eventually and ascend. The leading branches are mostly erect, and aid in the heightening of the tree. Some individuals of the ordinary trees recurve branches in great numbers when these are several years old; other specimens show no recurving of individual branches. The recurving of weaker branches is a common feature. *A. saccharinum,* the common Sugar Maple, seldom recurves the larger branches; but the weaker ones frequently begin to curve when two or three years old, and continue to such an extent as often to form almost a circle. The species can be recognized at long distances by this character. In *A. rubrum,* the Red Maple, I see no disposition to curve; in *A. platanoides* none; but it occurs to a small extent in *A. Pseudo-Platanus.* *A. macrophyllum,* the Oregon Maple, has the branches at a rather acute angle, with an incurved apex. This character seems unchangeable, and my thirty-year-old tree has a broomy character. *A. campestre, A. lætum* show no curving characters.

Negundo.

In the Ash-leaved Maple I observed no tendency to curve in either the Atlantic or Pacific coast species.

Sophora.

Neither in this nor in *Robinia, Gleditschia* nor any leguminose plant have I noted any disposition to curve mature branches.

Pyrus.

In the rosaceous family the Pear is characteristic in recurving its mature branches as it advances in life. In my earlier years the familiar arching was attributed to the weight of fruit. This I have found erroneous. The curving of the large branches does not begin until the tree has reached nearly the height it is to eventually become. It is not seen on younger trees, no matter how much fruit they may have to bear. This is also true of the Apple. The Cherry does not curve. The *Cerasus serotina,* Wild Cherry, shows no disposition to curve, but in old specimens of *C. Padus* the maturer lower branches often curve considerably. In *Cratœgus, Amelanchier,* and allies no tendency is observable.

Cornus.

Old bushes of *Cornus Mas* have the branches curved considerably with age. *Nyssa,* the Sour or Black Gum, starts horizontally from the first.

Diospyros.

Diospyros Virginiana, the Persimmon, has its branches more or less tortuous at an early stage, but in about ten years the laterals become more horizontal, and the ends of the branches curve up from the fifth year's growth.

Halesia.

In *H. tetraptera* and *H. diptera* there is no apparent curving, but *H. Meehani,* a remarkable seedling sport in my garden from *H. tetraptera,* has erect branches that recurve remarkably when a few years old, giving the tree a curious wind-swept appearance.

Catalpa.

Catalpa bignonioides and *C. speciosa,* old trees, give the impression of curvature with age, but I have not been able to decide this to my satisfaction. The tortuosity may be due to early growth alone.

Laurus.

The branchlets of *Laurus Sassafras* start out in early life at an angle of about 45°, but after about five years assume a horizontal direction. The succeeding branch system is tortuous, but seldom becomes decumbent.

Morus.

The Mulberry family shows little disposition to depart from the original plan of divergence. In some specimens of *Morus alba* I have seen some of the lower branches curved, which must have occurred late in life, but this seems exceptional.

Platanus.

In *P. occidentalis* I have found no sign of adult curving, but in *P. orientalis*, the European species, the laterals change from angular divergence to horizontal positions, and even recurving in many cases.

Juglans.

The Walnut family, I believe, retain their early character through life, though the English Walnut has a tortuous appearance.

Quercus.

It is in *Quercus*, or the Oak family, that we find the most interest, as the numerous species afford material for comparison. The angular divergence and ultimate positions seem so characteristic that we may have a reasonable assurance of the species when a tree is seen from a rapidly passing railroad train. *Quercus palustris*, the Pin Oak, is a good illustration of what occurs in many species (Plate XVII).

The upper branches grow at an acute angle, but after about five years proceed to decline, the point of departure being at the base, near the main trunk. By fifteen years they have become horizontal, and continue declining until the divergence again reaches an acute angle. Much the same procedure marks *Quercus Phellos*, the Willow Oak. *Quercus tinctoria*, the Black Oak, has the lateral branches horizontal at an early age, but I have never found any go lower. This is true of the *Quercus coccinea*, the Scarlet Oak, though to a less degree (Plate XVII). *Quercus bicolor*, the Swamp White Oak, departs from its angular position toward the horizontal when about ten years old, but never gets below the horizontal line. *Quercus macrocarpa* (the Burr Oak), *Q. lyrata* (the Over-cup), *Q. Prinus* (the Rock Chestnut), *Q. rubra* (the Red), I have not found to vary from the original framework. This also seems true of the European *Quercus Robur*, *Q. Cerris* (the Turkey Oak), and of the Japan *Q. dentata*. *Q. alba*, with its frame of branchlets almost as huge as its trunk, has been a puzzle to me. I am inclined to believe that the angular divergence of the lateral branches has not changed from the original plan. It may be noted that most species of Oak, when growing and in nursery rows, produce some weak side branches that soon become horizontal and finally curve.

Liquidambar.

The Sweet Gum, *Liquidambar styraciflua,* seems never to change the angular divergence of its laterals so far as a few inches from the base is concerned, but at a little beyond this they commence to decline at about ten years old in much the same manner as the Pin Oak, but eventually they take an upward bend, so that there is a curving and incurving feature as in the Norway Spruce.

Fraxinus.

The Ashes, as a rule, retain their original plan through life, but *F. Americana* and *F. sambucifolia,* the White Ash and the Black, become very much curved in the older branches.

Salix.

In the Willow family I have noted no departures from the original plan; the weeping variety of *Salix Japonica,* the well-known Weeping Willow, excepted, as already noted.

Ulmus.

There seems to be some tendency in young plants of *U. racemosa,* the Thomas Elm, to have the weaker branchlets recurve; but I have no mature specimen.

Coniferæ.

In the Cypresses, Junipers and some Pines I have found no evidence of the curving of mature branches, but in the Pines, Firs and Spruces the fact is self-evident. The upper series of about ten years of branching take an acute angle, then a horizontal direction at the base, which is eventually recurved, and finally an incurving occurs toward the younger portion of the branches. In many Pines—*Pinus pungens,* for instance—when the natural height is about reached, the upper branchlets become horizontal. The top of the tree is often as flat as if sheared to make a plane surface. Judging by pictures of European scenery *Pinus Pinea* has this habit in the Old World.

Among monocotyledons, I have noted in the South specimens of *Chamœrops Palmetto,* that had been evidently turned aside some-what in their earlier growth, that had curved the main stem in the effort to secure again the upright position.

The facts adduced reveal to us a stupendous power in plant life, of which biologists hitherto have taken little heed. True we have had casual notes of mushrooms lifting heavy paving stones in a single night; of the roots of trees throwing down stone walls and cleaving dense rocks in wedge-like fashion. I have myself recorded a case where a large tree growing on a rock had by accretions below lifted the whole of its immense weight of trunk and branches, so that it did seem that the trunk had elongated and that a side branch had been carried several inches above its original distance from the ground, but the great significance of these facts has not been made clear to us. The action of light, of gravitation, or of any external condition as a factor in direction fails to satisfy us. It has been usual, especially of recent years, to refer to conditions of environments as accounting for many of the phenomena of life. Undoubtedly these conditions must operate to some extent, or the speculations based on them could not command the assent of so many great minds. We know, for instance, that a plant growing vigorously in a cellar or dark room will incline toward the light; but I have shown in the *Proceedings* of the Academy that in the dense darkness of mines species of Agaric, growing from the roof or sides, curve their stipes upwardly, as do mushrooms that spring up in a dark night on the side of a sloping bank. I have also shown in the same publication that many plants closely observed by me carry on their curving operations by night rather than in the light of day. So in regard to the thought that the operations of plant life are carried on for individual good—the great weapon in the battle for life among modern hypotheses of evolution, this must be true to a limited extent. In the case of the *Magnolia acuminata* herewith illustrated (Plate XVI), we can see that if the curvings of the young shoots continued without any change in the original direction of the main laterals, the head of the tree would become as round as a cabbage and the interior branches would be smothered out. The declination in time gives scope to the young growth, and even the final uprising of the branch toward its apex is still kept within regulation distance of its fellows. In the Fir and Spruce the self-utility of the curvatures is clearly apparent. The tree could scarcely keep a mass of foliage in healthy condition wholly to the ground if it adhered strictly to the acute-angular method that marks the upper growths.

So far we may trace the effort for individual benefit in the direction changes, but that conditions of environment are active forces in the work may well be doubted from the fact of great variation in the degrees of curvature.

It has already been stated that the observations were made on my own grounds. Comparing, however, trees of my own with others of the same species on neighboring properties, we find wide divergencies. In some trees of the same species there will be few illustrations of curving, while in others nearly every large branch will take on an arcuate form. This fact is illustrated in Plate XVI of *Magnolia acuminata.* The two trees are within thirty feet of each other. The one on the right shows considerable incurving. The upper branches have retained their original angular divergence, and the bend toward the horizon as age advanced has been gradual; only a few at the base and on the one side have reached that point. We can see that if this tree had wholly lost the recurving power we should have a fastigiate individual, closely imitating a Lombardy Poplar in form. But the one on the left took early to recurving, and to such an extent that it seemed to the good of the tree that these should ultimately incurve in order to afford room for a healthful branching development.

With all these individual variations there is still a general character assumed by each species, by which it may be distinguished as well as by the characters derived from leaves, flowers or fruits. In *Quercus palustris,* for instance (Plate XVII), there is little disposition to curvature in the decumbent branches. They bend very close to the main trunk. They commence to diverge when about five years old, and the continuously increasing degree of divergence can be seen at a glance. This character will vary more or less in different trees, but there is almost always enough in evidence to enable one to distinguish the Pin Oak from other species. The Scarlet Oak, *Quercus coccinea,* rarely shows any disposition to curve mature branches. A representation of this species is given on the right hand of the Pin Oak (Plate XVII). But here we may note again that there is no necessity for it, as the original angle of divergence is sufficient to allow for a fair development without subsequent change. May we not borrow a simile from a class of metaphysicians who contend that "man is not merely a creature of circumstances, but his character is mainly made for him and not by him," and believe that an inborn direction, and not environment to any great extent, is the ruling power in vegetable life ?

What is the nature of this power that is capable of bending with ease and without a break an old branch or trunk of a thickness that would require an immense mechanical pressure for man to accomplish ? How does it operate ?

In the paper already cited[1] I drew attention to the fact that the life-growth of a plant was in a measure a struggle against gravitation, and that a great part of the nutrition prepared by the plant was spent in supplying energy in this struggle. Consequently when a plant received extraneous aid in the contest, the extra nutrition saved by this assistance was diverted to extra growth and luxuriance. Many observations have since shown that to energy transmuted from nutrition we have to look for the various forms that plants assume. To the highest degree of energy we may attribute the chief triumph of growth force over gravitation. This is exemplified in the leading shoot of Pine trees. Observers know that in this leading shoot the highest vegetative force is exhibited. It so successfully resists all gravitating influences that it is drawn in no degree from an exact perpendicular. If, however, the main growing shoot of a vigorous tree is broken off, the extra nutrition diverted from the centre to the lateral branches supplies one of these with an extra degree of energy, and a new leader arises in place of the lost one. From this we deduce the law that plants are engaged in a contest with gravitation, and that geotropism is in proportion to the degree of energy lost in the contest.

Going over the list of plants enumerated in this paper, we note that decumbency is in proportion to the decline of vigor, and we find this to be the case in individual trees generally. What are known in gardens as fastigiate trees, of which the Lombardy Poplar is a type, are remarkable for the vigor of the central shoot and laterals. Weeping trees, on the other hand, are characterized by decreased vigor. The normal form of *Salix Japonica*, of which the so-called Babylonian Willow is an offspring, is very strong in comparison with the variety. The Kilmarnock Weeping Willow is weak in comparison with *Salix caprea,* its parent, and this is true of all the weeping trees in gardens—they are all in various degrees more slender and delicate than the normal forms of the same species.

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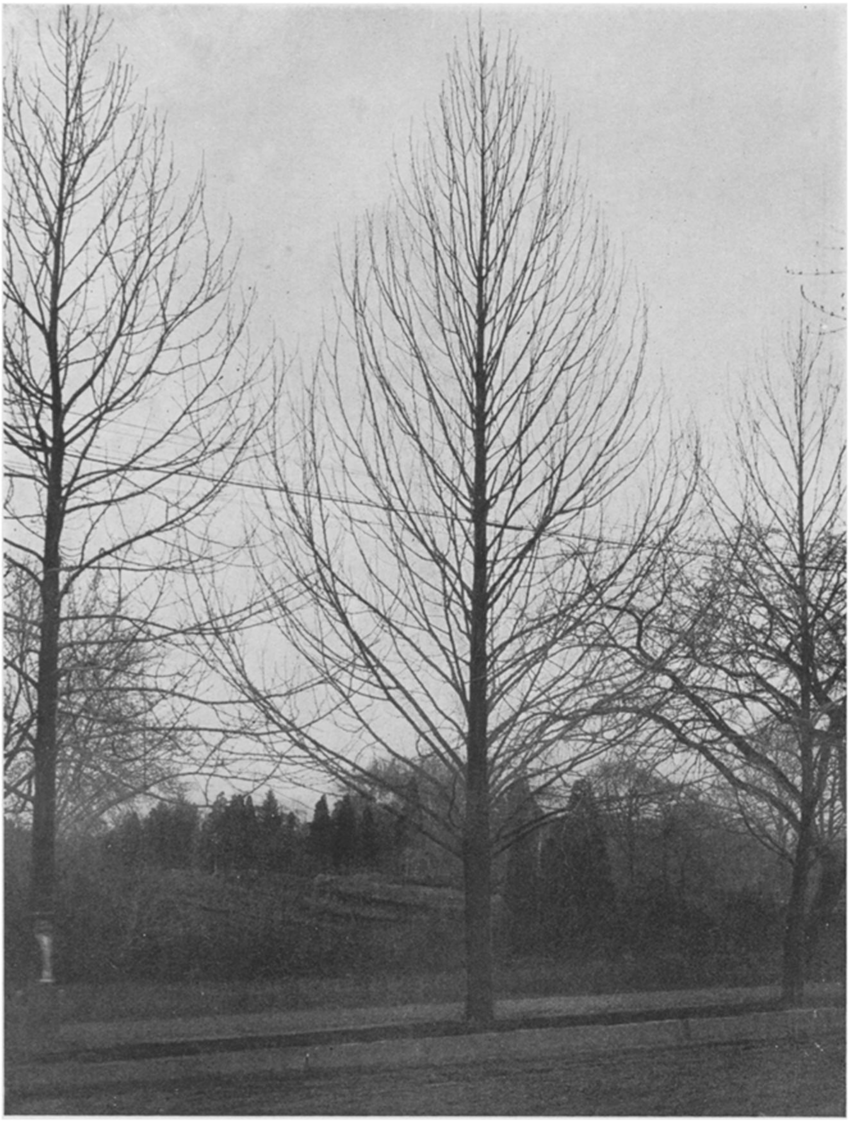
[1] *Proc. Acad. Nat. Sci. Phila.*, 1866, p. 401.

The ability to overcome gravitation has been lost, in proportion to the lessened degree of energy.

How does this view account for the case of the incurving of branches that have become decumbent ?

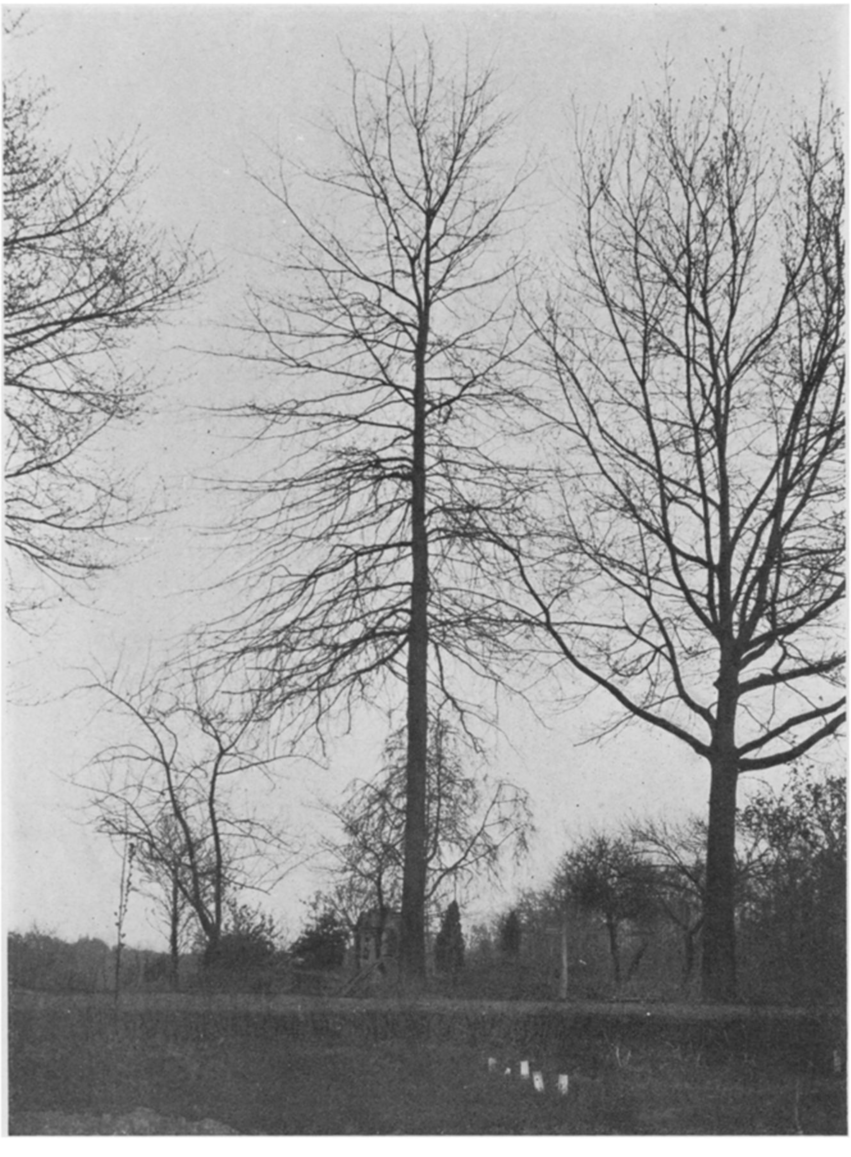
It seems like a mere restatement of the fact to say that the incurving branch has simply regained a power to successfully resist gravitation it had never wholly lost. When we note, however, that these incurves are all methodical, and only occur when they are evidently beneficial to the plant, we may infer that energy itself is not blindly directed, but is under the control of a life-power within the plant that is able to strengthen a weak position when it is for the general good. We see this when it undertakes to heal a wound; we only extend our view of this power to meet these new cases.

In conclusion, trees have the power, not merely to grow into various forms as it is usually understood, but to bend mature branches when exigencies require it; and this display of power results from varying degrees of energy employed by plants in their struggle with gravitation.



MAGNOLIA ACUMINATA.

MEEHAN. BENDING OF MATURE WOOD IN TREES.



QUERCUS PALUSTRIS. Q. COCCINEA.

MEEHAN. BENDING OF MATURE WOOD IN TREES.